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FOREST HEALTH PROTECTION
SOUTH SIERRA SHARED SERVICE AREA

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From: State and Private Forestry, Forest Health Protection, South Sierra Shared Service Area

Subject: **Situation Summary of recent tree mortality on Sequoia National Forest**

Introduction

2014 was a particularly harsh year for the state of California's forests, trees, and people. Unusual warm winter temperatures, below-average precipitation, and large-scale wildfires were record-setting. The high level of bark beetle-associated mortality occurring in Sequoia National Forest is not unique, but widespread throughout southern Sierra Nevada and southern California. The Sequoia National Forest has been experiencing drought effects for a number of years, but dramatic surges in bark beetle-associated mortality are increasing. Tree mortality directly associated with low precipitation is also evident. The Forest and surrounding communities are being significantly affected by mortality: hazardous trees along major roads and private property; increases in fire danger; and impacts on forest recreation. Recent aerial and ground surveys indicate significant levels of bark beetle-associated mortality. This report focuses on current tree mortality, and potential bark beetle infestation in the Forest and surrounding communities.

Figure 1. *Numerous tree deaths in a small drainage, backside of Greenhorn Summit, Kernville Ranger District.*

Probable Causes

Two factors are most likely driving insect-associated mortality: high tree densities in many areas, and trends of drier, hotter climates. Current stands are often overstocked and highly susceptible to drought, wildfires, and native pests. The most recent snow surveys (provided by California Cooperative Snow Surveys, May 13, 2015) show that southern Sierras was 0% of normal for this time of the year, and 0.1 inches in average snow water. The statewide summary sits at 2% of normal, and 0.2 inches of average snow water (http://ca.gov/drought/). In California, increases in conifer mortality are often (negatively) correlated to an average annual precipitation (mean PDSI[1]) that is below normal consecutively for at least three years prior (Oblinger et al. 2011) (see Figure 2). Considering the previous extended drought period, and higher than normal temperatures this past year, it is not surprising that more acres were detected with bark beetle-associated mortality. Annual lack of precipitation throughout the state has progressively worsened since 2011, while record-setting warmer temperatures occurred in winter and summer.

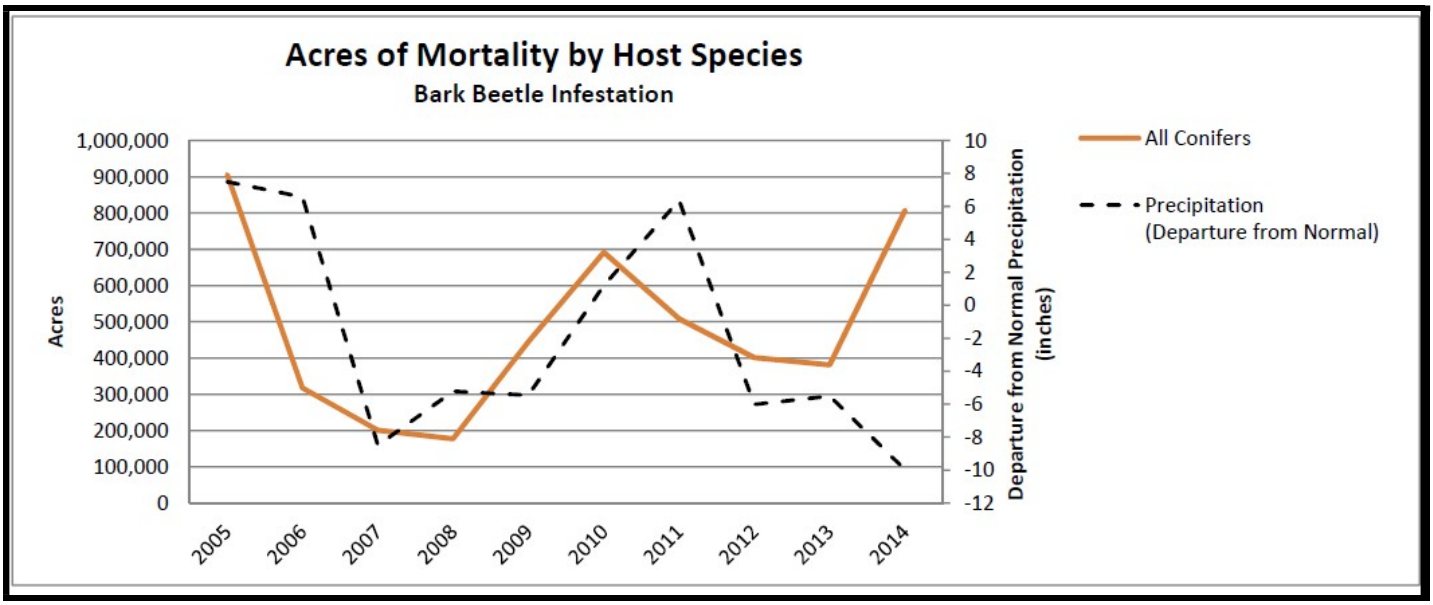


Figure 2. *Graph of mapped pest mortality vs. annual CA precipitation, 2005-2014.*

Current Forest Status

As the southern-most Forest in the Sierra Nevada range, drought stress effects are often observed in Sequoia National Forest before those further north. High levels of damage and mortality associated with drought and pests in the Forest have been ongoing since the last drought event ~2007. Grey pines have been declining around Lake Isabella for several years due to dwarf mistletoe, wildfires, and possibly drier soil conditions. Sugar pines of all sizes have been declining, as individuals or small groups, due to white pine blister rust (*Cronartium ribicola*) and/or bark beetles responding to lack of available water for tree function and defense mechanisms. Trends that pest activity was increasing were first noticed in 2008 in the higher elevations. Record low precipitation beginning winter of 2006-2007 did not improve until winter 2010-2011, but that water recharge is depleting. True firs and incense cedar were seen fading as early as autumn of last year, now entire hillsides of declining cedars are clearly visible.

[1] *Palmer Drought Severity Index (PDSI) is a measurement of dryness based on recent precipitation and temperature. The index is often used in determining long-term drought.*

According to Forest Health Monitoring Aerial Detection Surveys (ADS 2011-2014)[2], overall bark beetle-associated mortality has been continuous and intensifying in various locations throughout Sequoia NF and surrounding communities (Appendix A-C) as drought has persisted. Identified patches with mortality associated with bark beetles have been as large as 3000 acres in 2014, along with a multitude of damage agents. Losses of trees have ranged from 5 to 100 per acre. Large acres of dead pinyon pine within Chimney and Owens Peak Wilderness (Bureau of Land Management) first noticed in 2014, were ground verified to be heavily infested with pinyon *Ips*. According to the most recent ADS flight in April 2015, an estimated 173,000 acres were affected by pest activity – a jump from 66,000 from last year[3] (see Table 1). Nearly 3 million trees were estimated to be recently dead, with about 2 million as ponderosa pines. There is a noticeable elevation break where mortality has been the most severe. Forests below ~5000 feet are experiencing the highest levels of mortality, particularly in ponderosa pine, sugar pines, and incense cedar. Pine die-off has been increasing in this Forest, but surged at the beginning of this year – with earlier season crown fading than in previous years. Evidence of decline or mortality is mixed in all affected stands; there is top-kill with fading in pines and unusual crown fading not often observed in the incense cedar. Unfortunately this lower elevation is where most communities interface with Forest Service lands, and here public safety is the primary issue.

Number of trees killed and acres with mortality, <u>all agents</u>, July 2014 and April 2015 from aerial survey.*

National Forest	Estimated trees 2014	Estimated trees 2015	Acres 2014	Acres 2015
Sequoia	**190,000**	**2,970,000**	**66,000**	**173,000**

Number of trees killed and acres with mortality, <u>western bark beetle only</u>, July 2014 and April 2015 from aerial survey.*

National Forest	Estimated trees 2014	Estimated trees 2015	Acres 2014	Acres 2015
Sequoia	**79,000**	**2,215,000**	**38,000**	**105,000**

**Mortality calculated for 2014 are only from areas that were resurveyed in 2015.*

***Table 1**. Comparison of mortality aerially detected in 2014 vs. April 2015 in Sequoia National Forest.*

Ponderosa pines in the lower elevation front-range have been the hardest hit by western pine beetle (*Dendroctonus brevicomis*, WPB) due to high proportions of large diameter, even-aged trees at high densities. Bark beetle activity is mostly concentrated on larger-sized pines with some "spill-over" occurring on smaller diameter neighbors. Natural stands and plantations are losing the largest-sized pines as beetles primarily select bigger trees to initiate attack on. Many locations are dramatically altered, particularly campgrounds and private homesteads with dead high-value trees (see Figure 3). WPB targets and thrives in these areas: stand basal areas above the threshold of eminent mortality (Oliver 1995) with 80% host composition, and stand diameter average of 13 inches or greater. These conditions are highly attractive to western pine beetle and more at risk when drought occurs. Attacked trees are turning color earlier in the season which has been alarming local residents and firefighters.

[2] *When looking at Aerial Detection Surveys, polygons are areas **with** mortality; entire polygon is not completely dead. Metadata associated with polygons give indication of level of pest activity.*

[3] *Comparison only of areas flown in 2014 and again in April 2015. Some areas were not surveyed in April, but will be completed summer 2015.*

Figure 3. *Recent ponderosa pine mortality surrounding the community of Pinehurst, CA.*

The sudden widespread mortality in incense cedar is more attributable to the severity of the drought rather than to native pests. All sizes of incense cedar are observed to be fading in Sequoia NF. There is no known primary bark beetle or other insect that mass-attack incense cedar. *Phloeosinus sp.* beetles are found in small branches and stems, and woodborer galleries are etched only in a few places on dead trees. *Armillaria* spp. and *Heterobasidion occidentale* root diseases are natives that appear occasionally as the cause for mortality in the Sierras; however, a large percentage of recent declining incense cedars show little to no pest presence. One noted fact is that cedars are fading within the same locations as ponderosa pines, an indication of overall declining site quality (see Figure 4). Where incense cedars appear to be dying in large numbers is within oak-pine types.

Trees with prior pathogen infection or injury will still be at higher risk than those without, particularly in true firs. Fir engraver bark beetles (*Scolytus spp*.) typically surge 2-3 years into an ongoing drought, and anticipated to increase in 2015.

Early leaf drop of (blue) oaks was detected along the entire western foothills of the Sequoia in 2013 and again in 2014 (east of Fresno); oaks now appear to be dying back branches but still retaining green buds.

Figure 4. *2015 Incense cedar mortality at Cedarbrook Picnic Area, Hume Lake Ranger District.*

In the upper elevations and on all districts, it is sugar pines and white firs displaying the most recent mortality as a result of drought conditions. Sugar pines have been declining for multiple years throughout California, but due to multiple factors. White Pine Blister Rust (*Cronartium ribicola*) is an exotic pathogen, introduced into the West nearly a century ago and has only been in Sequoia NF since 1970, has been very slowly decimating most five-needled white pines in western forests. In Sequoia NF where populations of white pines are scattered, this gradual disappearance can be unnoticeable but significant to stand diversity. Compounded with drought, all sizes and age classes are currently being killed by bark beetles. A few years ago it was just individual legacy-sized trees, now it is groups of 5-10 trees consisting of mature trees greater than 15 inches average DBH (see Figure 5). This accelerated loss of mature sugar pine affect cone production, stand diversity and composition.

Figure 5. *Group of recent sugar pines killed by mountain pine beetle, Greenhorn Mountains.*

White fir mortality is frequently associated with water years where precipitation is below average. By the third consecutive year of low precipitation, mortality is often found: on dry sites, root disease infection centers, or overstocked stands. White fir is most susceptible in root disease sites as attacked trees are most often already infected from neighboring hosts, and may have been attacked previously by engravers. Surprisingly, recent mortality is found on trees with severe true leafy mistletoe infection, *Phoradendron spp*. Fir engravers, woodborers, and dwarf mistletoe (*Arceuthobium spp*.) are also found in dying trees, but the prevalence of true mistletoe infection appears to be particular (see Figures 6 & 7). Many of these trees did not appear vigorous, nor was there much leaf crown initially.

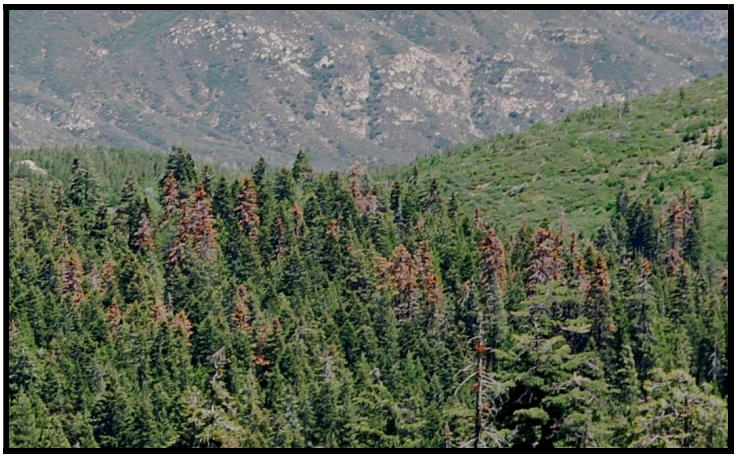


Figure 6 & 7. *Mortality of white firs heavily infested with true leafy mistletoe, Greenhorn Mountains.*

Hume Lake Ranger District

On Hume Lake Ranger District, tree mortality is plainly visible along Highway 180 and main side roads. The communities of Pinehurst, Badger, Dunlap, Miramonte, and Cedar Brook have multiple dead trees surrounding homes or structures. In Pinehurst, groups of up to 200 trees turned red in January 2015, 20-50 trees on average. In the district, pine plantations along McKenzie Ridge were first detected in 2012 where 7-15 ponderosa pine trees/acre were dead; most mortality focused where tree diameters were averaging 13-15 inches DBH, and spacing at ~12ft x 12 ft. Mortality was observed in 2009-2010, but confined to higher elevations where white fir and lodgepole were noted. By 2011, mortality had shifted to lower elevations and ponderosa pine-killed groups had been growing and expanding. Pinehurst and surrounding communities are actively in the process of removing dead/dying trees around homes and structures.

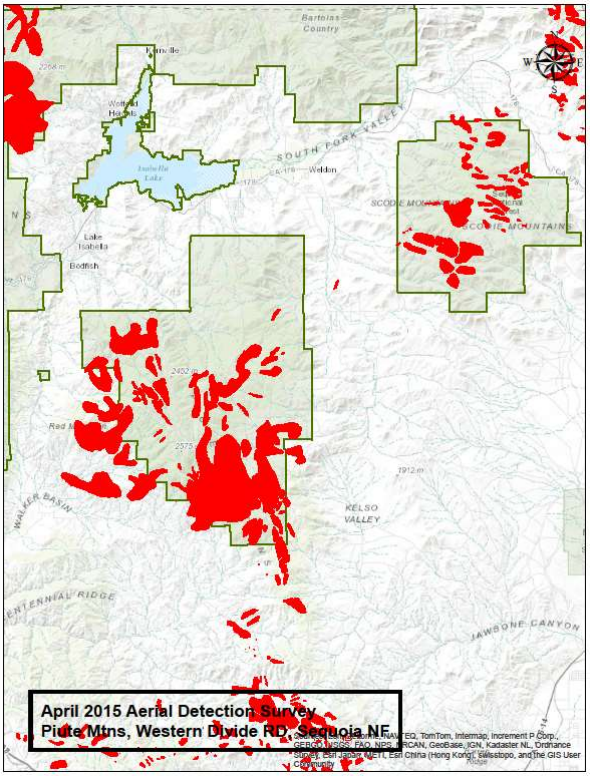
Western Divide Ranger District

The size and difficulty of access for the Western Divide and Kernville RD required using Aerial Detection Surveys (Forest Health Monitoring, Region 5) in addition to ground surveys to assess recent and older mortality. A quick glance at the recent 2015 ADS shows much of the district as large red polygons with varying levels of pest activity and mortality. Mostly depending on the location and elevation, tree mortality shifts among tree species.

Figure 8 . *Tree mortality in Tyler Creek watershed, north of California Hot Springs, Western Divide Ranger District.*

The largest losses of incense cedars in all size and age classes appear to be below 5000 feet which is primarily oak woodlands, recently transitioning into mixed-conifer (see Figure 8) – perhaps now reverting back to oak woodland. Densities in these areas are already high, especially around communities like White River and Pine Flat where trees provide shade and natural barriers. Not all cedars are dying, but rather showing symptoms of adaptation to drier conditions that may look like decline: lower crown branches are being rapidly shed that give the appearance of a previous low intensity fire (see Figure 9).

Figure 9. *Mortality and limb dieback on incense cedars, Pine Flat area, Road 23S05, Western Divide Ranger District.*



Kernville Ranger District

Mortality in this large district could be considered higher than the others due to the inclusion of pinyon and gray pine mortality in the lower elevations. Pinyon mortality has increased significantly according to the April 2015 survey; most heavily hit areas are the Piute Mountains and Scodies. Groups of mortality mixed with Jeffrey pines range from 2-10 trees per acre. Pinyons were heavily infested with *Ips spp,* and in the same stands the gray pines were being killed by a completely different complex of damage agents. Campgrounds around Lake Isabella are rapidly losing mature grey pines during the drought but also to small wildfires. Little to no regeneration is found in the understory as necessary replacements. Dwarf mistletoe infections are fairly severe on declining grey pines, but do not fully explain mortality. FHP is continuing to monitor and investigate the recent decline of gray pines in the Sierras.

Mortality of lodgepole and Jeffrey pines in the higher elevations are not as observable, but large polygons with mortality were detected in aerial detection surveys. Areas with 200-500 acre patches were noted with 1-3 trees recently dead per acre for both species. New group kills were found in the Greenhorn Mountains, but did not appear to be building rather just removal of the weakest trees in the stand. Jeffrey pine beetle (*Dendroctonus jeffreyi*) will outbreak a few years into severe drought events (Egan 2012). On Lake Tahoe Basin, Egan (2012) found that Jeffrey pine beetle reached epidemic or outbreak every drought period where PDSI (Palmer Drought Index) dropped below -3 for several consecutive years. Lodgepole pine mortality due to mountain pine beetle (*Dendroctonus ponderosae*) in California does not reach epidemic status as in Rocky Mountain regions, but can be just as devastating and stand-altering.

Assessing potential risk due to damage agents

Risk Mapping is geospatial analysis tool developed by Forest Health Technology and Enterprise Team (USDA Forest Service) to determine areas at "risk" for bark beetles or other damage agents based on stand/site properties and conditions. Risk is defined as a 25% or more volume loss over the next 15 years, including background mortality. Maps show potential impacts of insects and diseases at landscape scale to help land managers assess changes and prioritize areas for possible treatment (Appendix D); maps can also be separated by damage agent to distinguish varying degrees of impact per agent.

It is expected that mortality will continue regardless of whether or not adequate precipitation returns to the region. Pest Damage Inventories conducted by Forest Health Protection after the 1975-77 drought, indicated that mortality continued post-drought for at least two years despite the above-normal precipitation in 1978[4]. The highest mortality

[4] Information taken from Pest Damage Inventory 1975-1979; Sheri Smith, Regional Entomologist

was found on dry, south or west facing slopes, in low elevation and marginal sites – as is happening now. According to NOAA's National Weather Service website (*http://www.cpc.ncep.noaa.gov/*), above-normal rainstorms need to occur for several consecutive years in California to return to normal levels. Current drought monitors show the southern Sierra Nevada in "exceptional or extreme" drought conditions (US Drought Monitor, April 28, 2015). Forest trees will need more than several years of significant precipitation to recover vigor and regain sufficient resistance against bark beetles.

Despite expectations of mortality, strategies that improve individual tree and stand health are still strongly encouraged as prevention and resiliency measures. While these efforts reduce the proportion of susceptible trees, mortality may still occur due to drought and high beetle populations – this has clearly been evidenced in the current outbreak on the Forest. Districts should still prioritize highest risk areas, but also expect that scattered mortality will continue regardless. Emergency tree removals should focus on priority areas where dead trees will be public safety issues. Forest Health Protection staff are available to support planning and management that prevent and mitigate bark beetle-related mortality. Technical assistance and potential funding opportunities for project implementation are also available.

If there are further questions or concerns regarding this report and associated risk analysis, please do not hesitate to contact us.

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Furniss, R.L. and V.M. Carolin 1992. Western Forest Insects. USDA Forest Service, Miscellaneous Publication No. 1339.

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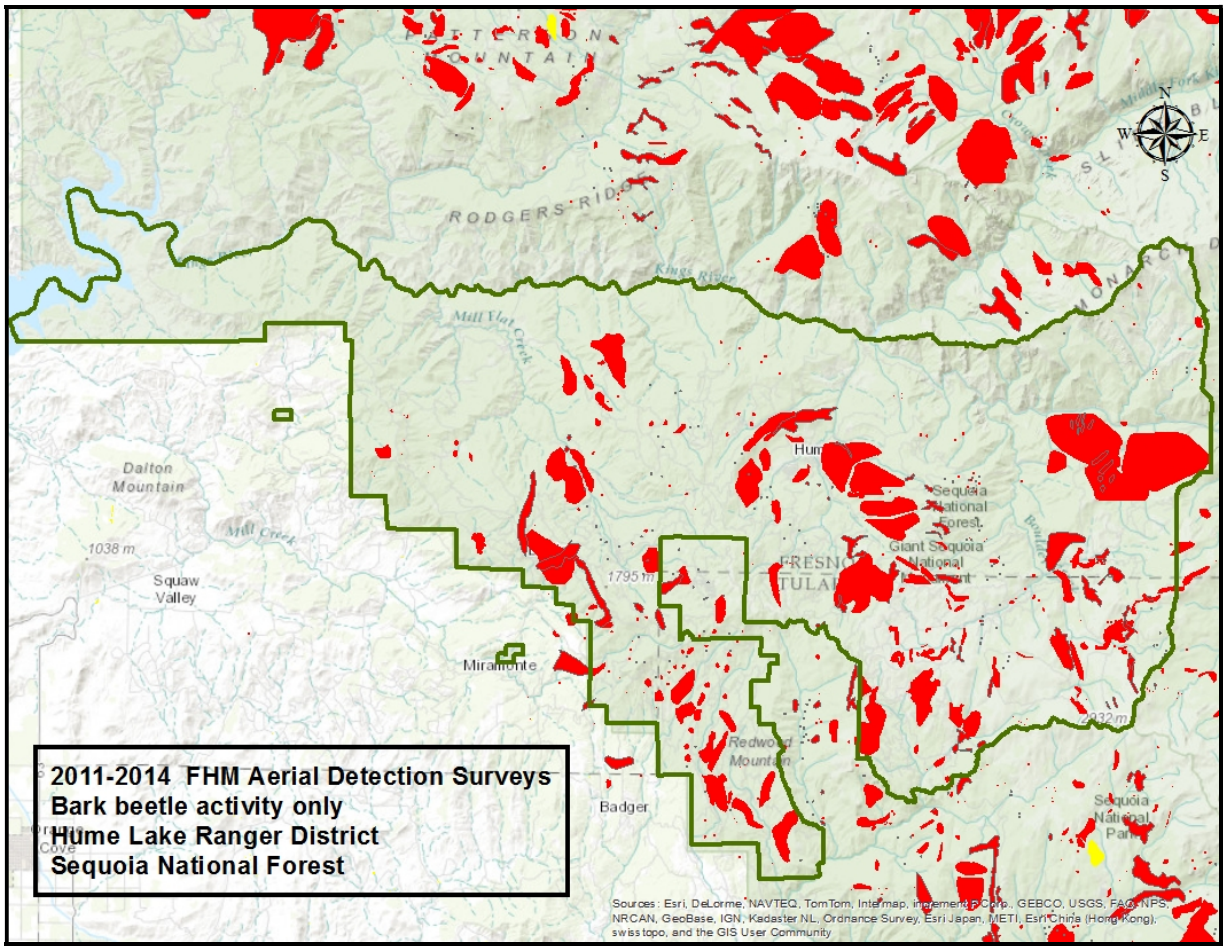
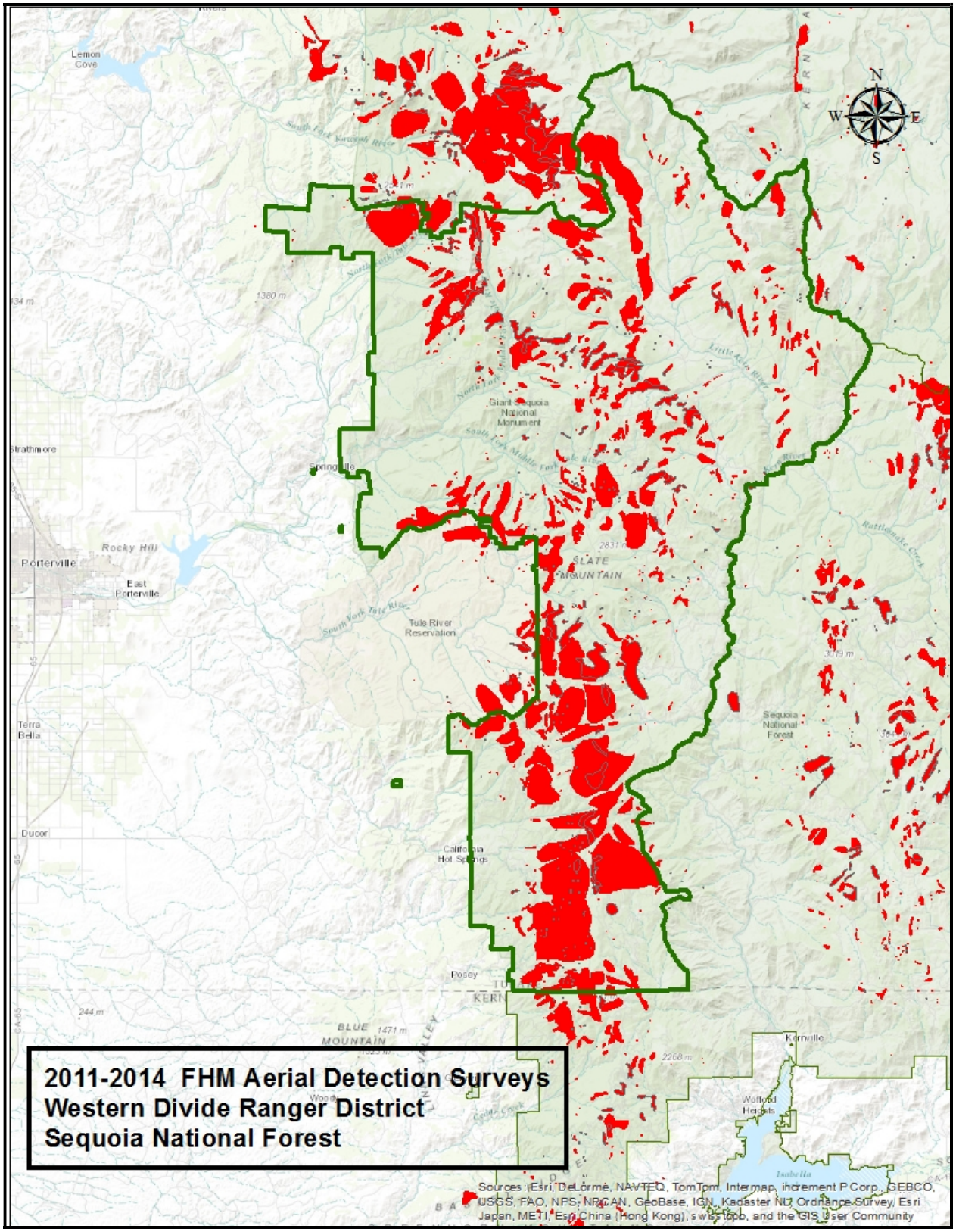
Oliver, W. W. 1995. Is Self-thinning in Ponderosa Pine ruled by Dendroctonus Bark Beetles? *In* Proceedings of 1995 National Silvicultural Workshop. USDA Forest Service, Forest Service, Rocky Mountain Research Station, GTR-RM-267. Fort Collins, CO. Pgs 213-218.

USDA Forest Service, Pacific Southwest Region, Forest Health Monitoring, Aerial Detection Surveys (2008 - April 2015), Davis, CA.

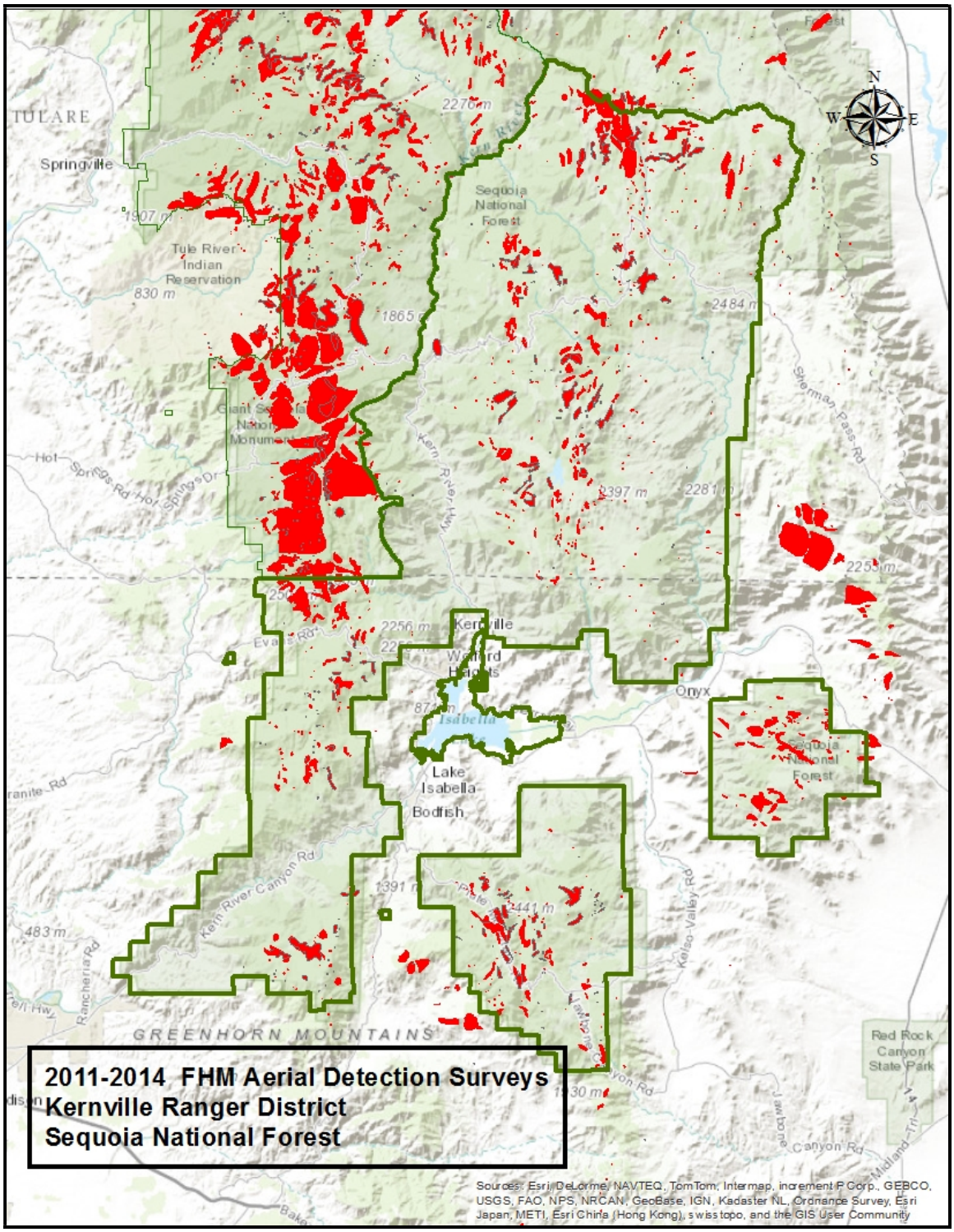
Appendix A. Compilation of 2011, 2012, 2013, and 2014 Forest Health Monitoring Aerial Detection Surveys on Hume Lake Ranger District, Sequoia National Forest. *Note: maps show only bark beetle activity, pathogens are not included.*



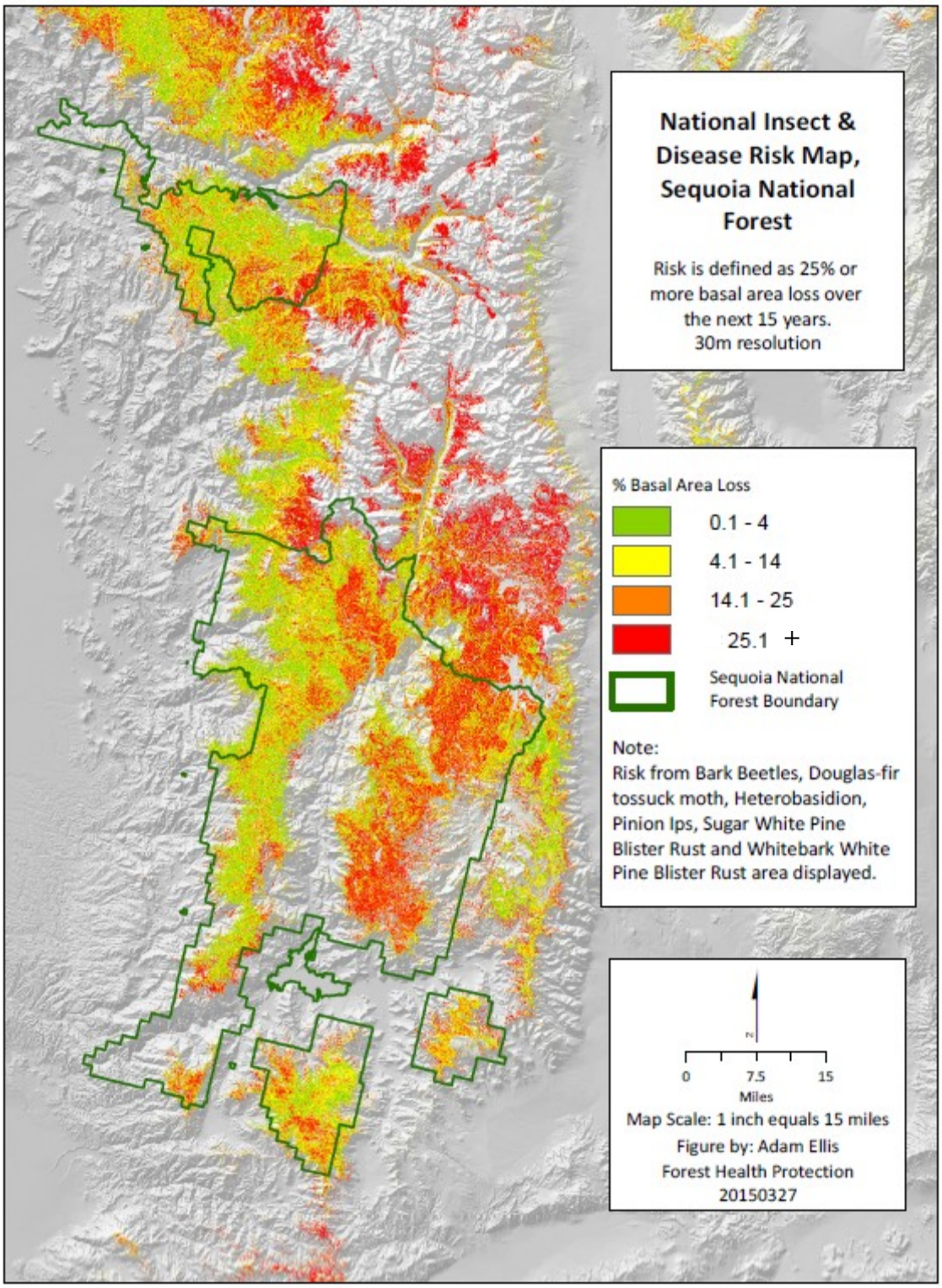
Appendix B. Compilation of 2011, 2012, 2013, and 2014 Forest Health Monitoring Aerial Detection Surveys on Western Divide Ranger District, Sequoia National Forest. *Note: maps show only bark beetle activity, pathogens are not included.*



Appendix C. Compilation of 2011, 2012, 2013, and 2014 Forest Health Monitoring Aerial Detection Surveys on Kernville Ranger District, Sequoia National Forest. *Note: maps show only bark beetle activity, pathogens are not included.* .


2011-2014 FHM Aerial Detection Surveys
Kernville Ranger District
Sequoia National Forest
TULARE
Springville
Tule River Indian Reservation
Sequoia National Forest
Kern River Hwy
Sherman Pass Rd
Kernville
Onyx
Lake Isabella
Bodfish
Kern River Canyon Rd
Kelso Valley Rd
GREENHORN MOUNTAINS
Red Rock Canyon State Park
Jawbone Canyon Rd
Sources: Esri, DeLorme, NAVTEQ, TomTom, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, and the GIS User Community

Appendix D. Insect and Disease Risk Map of entire Sequoia National Forest and other surrounding areas.
***Note**: map displays only particular damage agents listed in legend.*


National Insect & Disease Risk Map, Sequoia National Forest
Risk is defined as 25% or more basal area loss over the next 15 years.
30m resolution
% Basal Area Loss
0.1 - 4
4.1 - 14
14.1 - 25
25.1 +
Sequoia National Forest Boundary
Note:
Risk from Bark Beetles, Douglas-fir tossuck moth, Heterobasidion, Pinion Ips, Sugar White Pine Blister Rust and Whitebark White Pine Blister Rust area displayed.
0
7.5
15
Miles
Map Scale: 1 inch equals 15 miles
Figure by: Adam Ellis
Forest Health Protection
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